

# **How Surface Treatments Enhance Ground Handling**

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### **ABSTRACT**

Several runway surface treatments developed in recent years are described in terms of how aircraft tire landing and takeoff friction requirements are met, particularly during adverse weather conditions. Changing the surface texture with grooving, grinding and shot peening, use of chemicals to remove or prevent accumulation of natural or man-made contaminants, and the use of new techniques and materials are discussed as means of improving surface friction performance. Test data are presented to illustrate the effects of runway conditions on aircraft ground performance. The severity of the problem of operating on runway surfaces which cannot provide sufficient aircraft tire friction capability is also illustrated from documented aircraft accident/incident reports. The paper concludes with recommendations for future pavement research activities.

### **BACKGROUND**

Successful aircraft ground operations such as landing, taxiing, takeoff and aborted takeoff are influenced by a combination of pilot, aircraft and runway factors. Aircraft ground handling accidents (see figure 1) still occur although the frequency and severity have decreased in recent years. Improved pilot training, better aircraft braking/steering control systems and more

widespread installation of runway surface types and treatments have all contributed to this reduction despite a significant increase in number of overall aircraft operations.

In terms of wet runway performance, figure 2 illustrates how several different factors combine to produce the resulting aircraft performance level. This figure indicates that runway water depth and tire/pavement drainage capability combine to determine the friction coefficient available to help meet the aircraft stopping and steering requirements. The tire/pavement drainage capability is dependent upon not only tire tread conditions but also on the micro- and macro-texture characteristics of the pavement surface.

As indicated in figure 3, runway friction evaluations (see references 1 – 8) using both instrumented aircraft as well as ground test vehicles indicate that the slope of the tire friction/speed curve is a function of macro-texture and the friction magnitude is a function of micro-texture. Figure 3 provides a list of the different ground friction measuring devices used and the surface texture devices. Instrumented aircraft braking performance data were gathered using ten different aircraft ranging from a Sabreliner to a B-747.

This paper will discuss relatively new runway surface pavement types and treatments which offer improved tire/pavement friction performance primarily under the hazardous wet runway conditions. As expected, increased pavement surface texture can also increase tire wear rates. Federal Aviation Administration (FAA) Advisory Circulars (see references 9 and 10) describe three basic types of pavement surfaces: rigid, flexible and overlays. Subsequent sections of the paper will discuss characteristics of different surfaces in each of these categories and a hydroplaning pavement classification table will be given based on texture values.

## RUNWAY SURFACE TYPES

**Rigid Pavements** – These pavements normally involve the use of Portland cement concrete (PCC) as the prime structural element. Depending upon conditions, the pavement slab may be designed with plain, lightly reinforced, continuously reinforced, prestressed, or fibrous concrete. The upper slab surface may be finished, prior to the concrete setting up, using several different techniques including brooming, burlap drag, canvas-belt, float-finish and tining (plastic grooving). Once the concrete has set up and cured, several other treatments can be applied to increase pavement texture and tire/pavement drainage capability. Figure 4 shows a National Aeronautics and Space Administration (NASA) Wallops Flight Facility runway test section of ungrooved canvas-belt finished concrete and a similar section modified with a transverse saw-cut groove configuration. The macro-texture values went up significantly with the grooving and resulted in much higher wet friction values (see references 11 and 12).

An overall Space Shuttle landing facility runway schematic is shown in figure 5 with photographs depicting the middle transverse grooved section and the longitudinal ground section at either end. Application of the ground, or corduroy, surface in the touchdown areas resulted in reduced tire touchdown spin-up wear and still maintained 75 percent of the middle section's wet friction performance (see reference 13). Further modification using a Skidabraider shot peening treatment permitted adequate wet friction capability with acceptable tire wear rates for Shuttle landing operations to occur at up to 20 knot crosswinds. Another very efficient use of this shot

peening technique is in the removal of rubber deposits which build up in the runway touchdown areas. High pressure water and/or chemical treatments have also proven effective for rubber removal but the shot peening methods appears to give longer lasting good wet friction performance.

Another use of concrete to provide suitable aircraft operating surfaces is in fabricating interlocking paver blocks (see reference 14) and installing on taxiway and ramp areas. Several different paver block configurations (see figures 6 and 7) were investigated at NASA Langley's Aircraft Landing Dynamics Facility (ALDF) to determine wet surface friction capability. These test results indicated that the paver blocks could provide as much as 75 percent the friction performance of a grooved surface. A taxiway/ramp installation of paver blocks in a herringbone pattern is shown in figure 8. One other obvious advantage of paver blocks over conventional pavement surfaces is the ease of maintenance and/or repair.

**Flexible Pavements** – Flexible pavements support loads through bearing rather than flexural action. They are comprised of several layers of carefully selected materials designed to gradually distribute loads from the pavement surface to the layers underneath. The bituminous wearing course surface is comprised of a mixture of various selected aggregates bound together with asphalt cement, heavy grades of tar, or other bituminous binders. Its function is to prevent the penetration of surface water to the base course, provide a smooth, well-bonded surface free from loose particles, resist the stresses developed as a result of aircraft loads and furnish a skid-resistant surface without causing undue wear on tires. An example of a flexible asphalt surface at Wallops is shown in figure 9 and figure 10 depicts the three different grades of asphalt surfaces; namely, dense, open and gap or stone mastic asphalt. Percent mix air voids vary from 3-5 for the dense, 18-20 for the open and 3-5 for the gap grade. Stone mastic asphalt (SMA) is basically a wearing course mix with a high proportion of coarse aggregate content, which interlocks to form a stone-on-stone skeleton to resist permanent deformation. The mix is filled with a mastic of bitumen and filler to which fibers are added. This SMA wearing surface has proven to be quite durable with a high macro-texture and hence, better than average wet friction performance (see reference 15).

**Pavement Overlays** – Runway pavement overlays are usually undertaken to correct deteriorating pavement surfaces, to improve ride quality or surface drainage, to maintain structural integrity, to increase pavement strength or to improve wet surface friction performance. Many of the newer overlays to improve tire/pavement wet friction performance are relatively thin, i.e. less than 25 mm. A close-up of one thin asphalt overlay surface installed at NASA Wallops Flight Facility is shown in figure 11. This particular overlay used small, hard, angular silicate aggregate rolled into a bitumen binder to an average thickness of 12-13 mm. Wet friction values measured at 65 km/hr were relatively high (0.85-0.90) but tire wear was also severe and nearly unacceptable.

Another popular overlay is called "porous friction course (PFC)", "open-graded mix" or "popcorn mix". An example of one installation is shown in figure 12. The runway shoulder without the PFC appears to be flooded during the rain event whereas the PFC surface appears to be only damp if not dry. Instrumented aircraft and ground friction measuring devices obtain wet friction values on PFC surfaces comparable to transverse grooved surfaces. The unique property

of this open grade asphalt is that it allows water to drain directly down to an impervious sub base and then off to the runway shoulders. One disadvantage is that rubber deposits in tire touchdown areas will decrease the water drainage capability and hence this overlay should only be used in the middle section of the runway (see reference 5).

**General Pavement Surface Hydroplaning Potential Classification** – Based on a wide variety of runway surface friction and texture measurement evaluations reported in earlier references identified in this paper, the table in figure 13 indicates five major pavement classes. A general description of the different pavement types with class I surfaces having the highest macro-texture depth values and class V surfaces having the lowest macro-texture depth values. Since the potential for dynamic hydroplaning varies inversely with the surface macro-texture, class I pavements are identified as having the least hydroplaning potential whereas class V pavements are considered to be the most susceptible. Using this pavement classification system as a guide for runway surfaces, airport operators should be encouraged to install class I or II pavement surfaces on their runways. If periodic macro-texture depth measurements indicate the runway surface is approaching a class IV category, corrective surface treatments, such as grooving, grinding, shot peening, overlays and/or rubber removal programs, should be implemented. It is also recommended that if a runway or portion of a runway surface is determined to be within class IV or V, adequate and timely notification should be given to pilots particularly during wet weather aircraft landing and takeoff operations.

### CONCLUDING REMARKS

The principal aircraft/runway factors which affect aircraft ground handling performance during wet runway operations have been reviewed. This review included identifying the relationship between tire/pavement friction performance with surface texture values and concentrated in the pavement characteristics which influence aircraft ground handling performance. A variety of rigid, flexible and pavement overlays were described and a pavement surface classification by hydroplaning potential was discussed. The findings from several research studies were discussed to underscore the complexity and variability which characterizes aircraft wet runway operations. These research efforts, however, have revealed several promising means, such as grooving, grinding and shot peening, which offer improved tire/pavement water drainage capability and hence, contribute to safer aircraft operations. In reviewing the many factors influencing aircraft wet runway performance, several approaches are recommended to alleviate the severity of the problem in the future: continue to update pilot education and training ; increase implementation of procedures/equipment for monitoring slippery runway conditions and identifying severity to the pilot; develop improved antiskid brake system performance; and prompt remedial treatment of runway drainage problems.

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# **Aircraft Landing Overrun Accident on Wet Runway**

**DC-9 Aircraft; Reynosa, Mexico; October 6, 2000**



Figure 1



# Factors Affecting Aircraft Wet Runway Performance

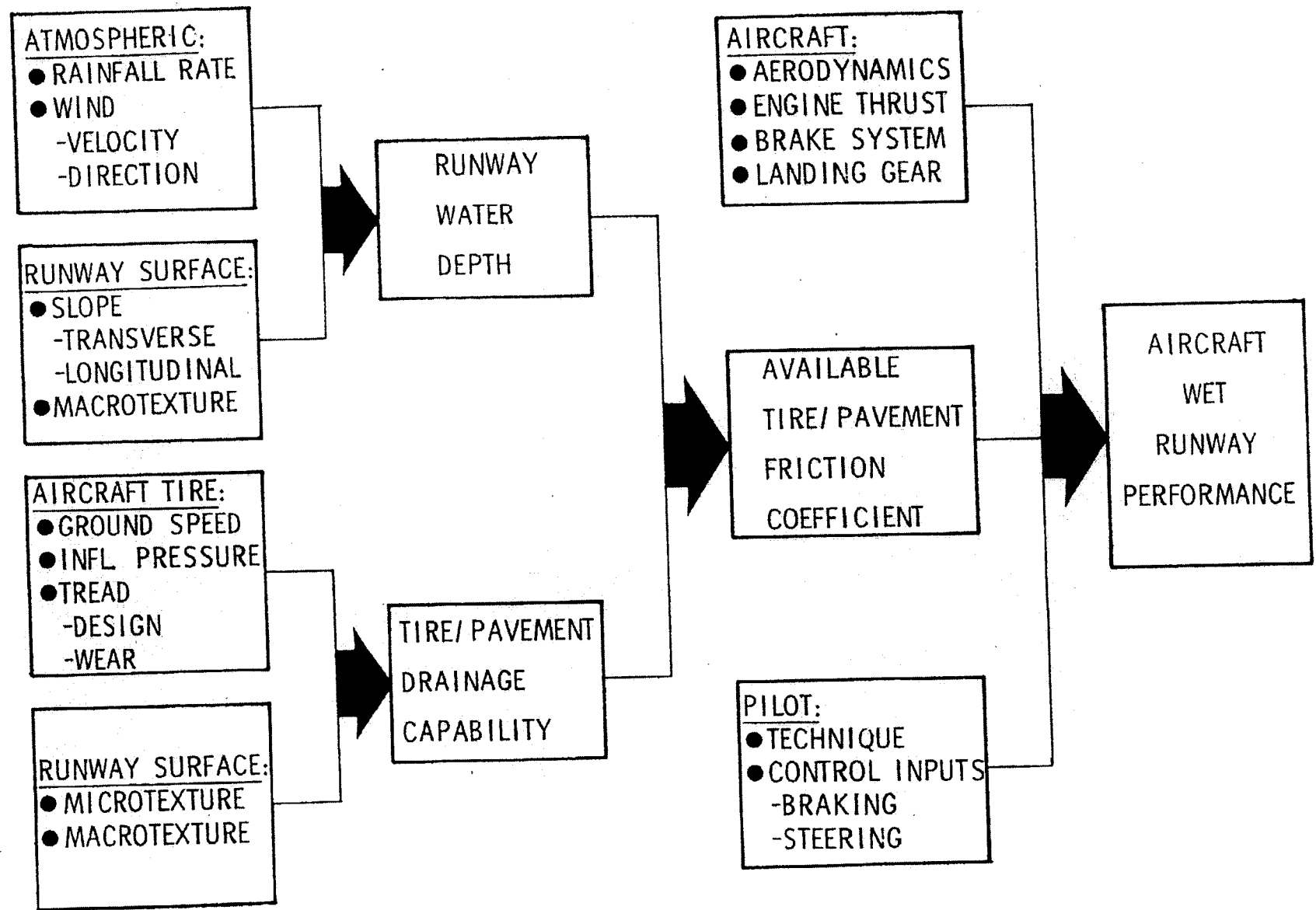


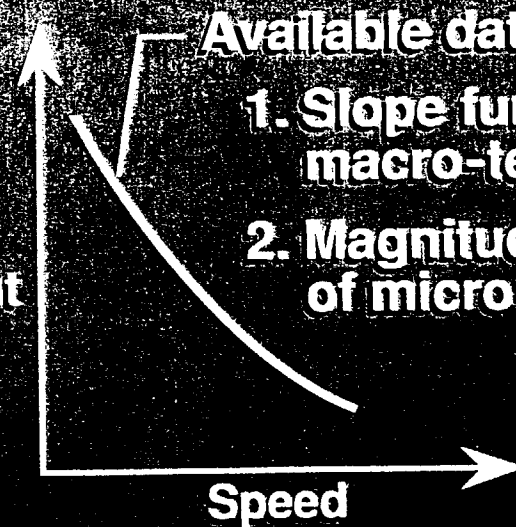
Figure 2

# RUNWAY SURFACE FRICTION EVALUATIONS

## Friction measuring devices:

- Diagonal-braked vehicle
- Runway friction tester
- Grip tester trailer
- Mu-meter trailer
- Skiddometer trailer
- E-274 skid trailer
- Surface friction tester
- Tatra friction tester
- Dynamic friction tester
- Instrumented tire test vehicle
- Helideck friction tester
- Norsemeter friction tester
- IMAG tester trailer
- ROAR trailer
- Drag slip tester

Friction  
coefficient



Available data suggest:

1. Slope function of macro-texture
2. Magnitude function of micro-texture

## Texture measuring equipment:

- Volumetric techniques
- Laser units
- Outflowmeters
- British pendulum tester

Figure 3

# CONCRETE TEST SURFACES

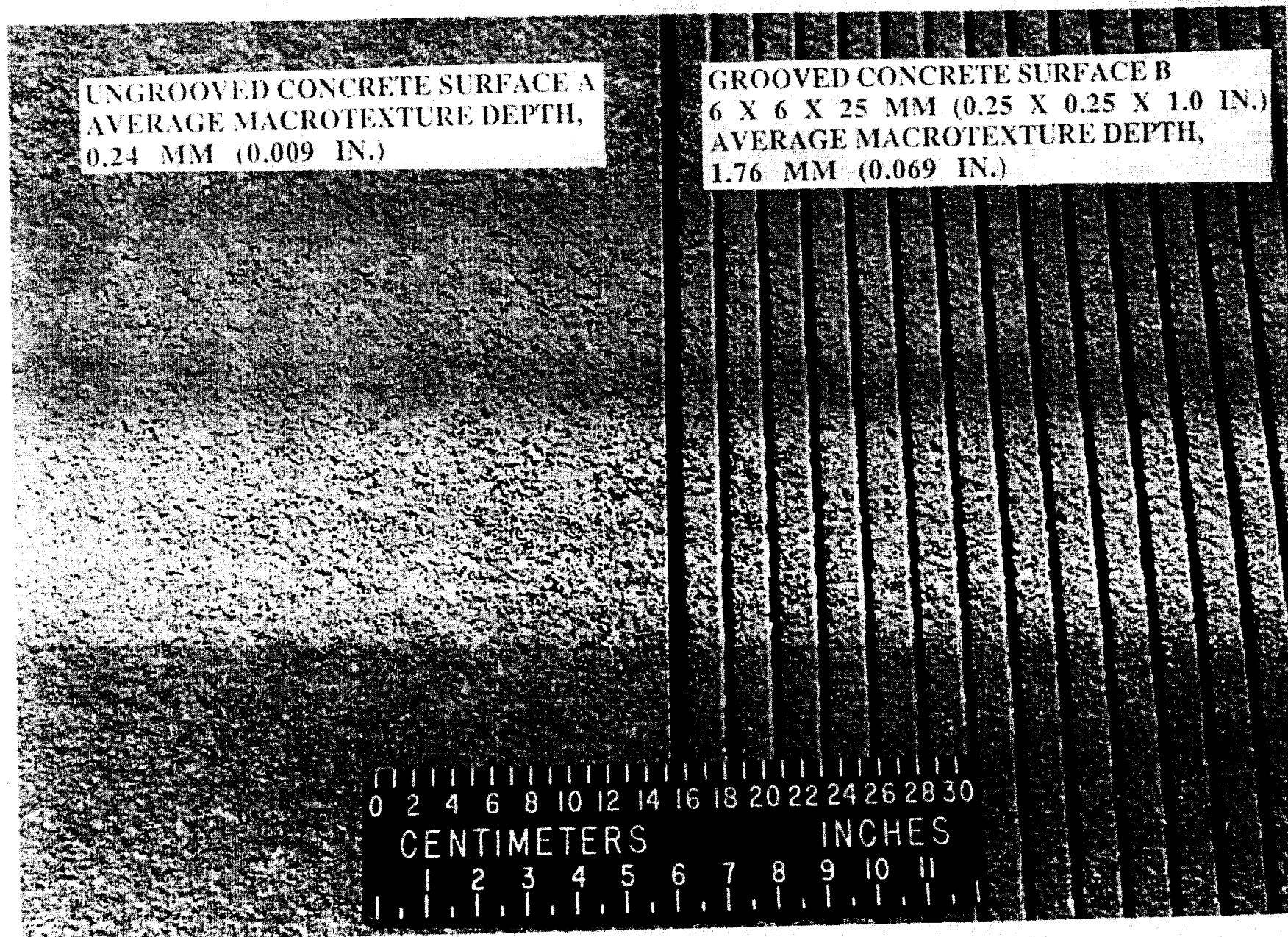
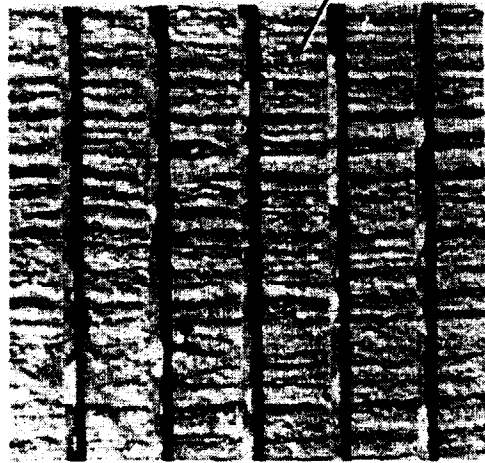
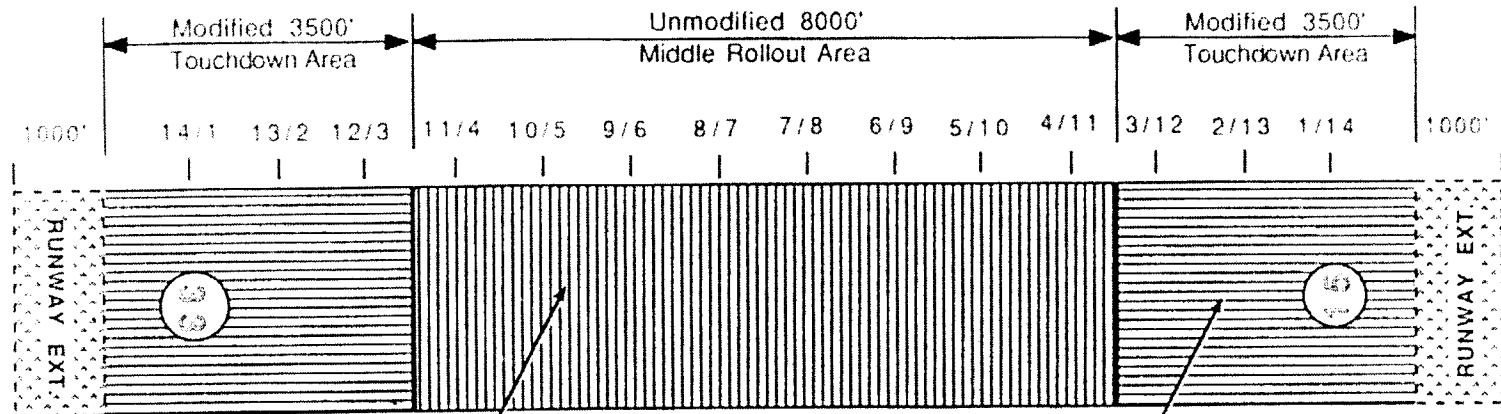


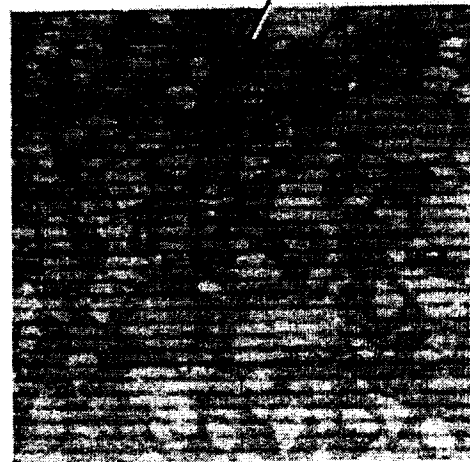
Figure 4

# NASA KSC SHUTTLE LANDING FACILITY

## MODIFIED SURFACE ARRANGEMENT



**TRANSVERSELY GROOVED**  
1/4 X 1/4 X 1 1/8 IN.



**LONGITUDINAL GRINDING**  
4 1/2 BLADES/IN., CORDUROY FINISH

Figure 5

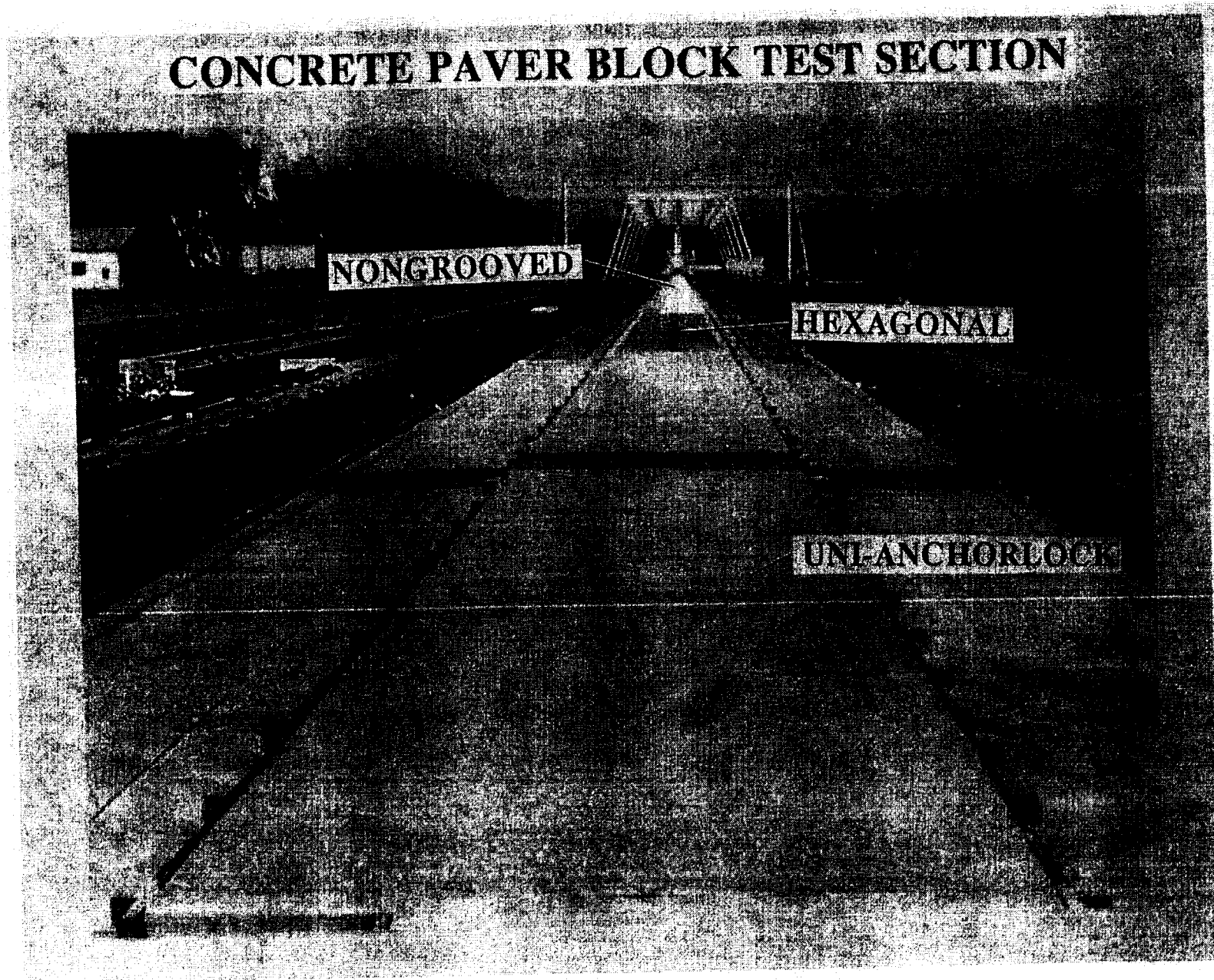


Figure 6



# CONCRETE PAVER BLOCK TEST SURFACE



Figure 7

# Taxiway Concrete Paver Block Installation

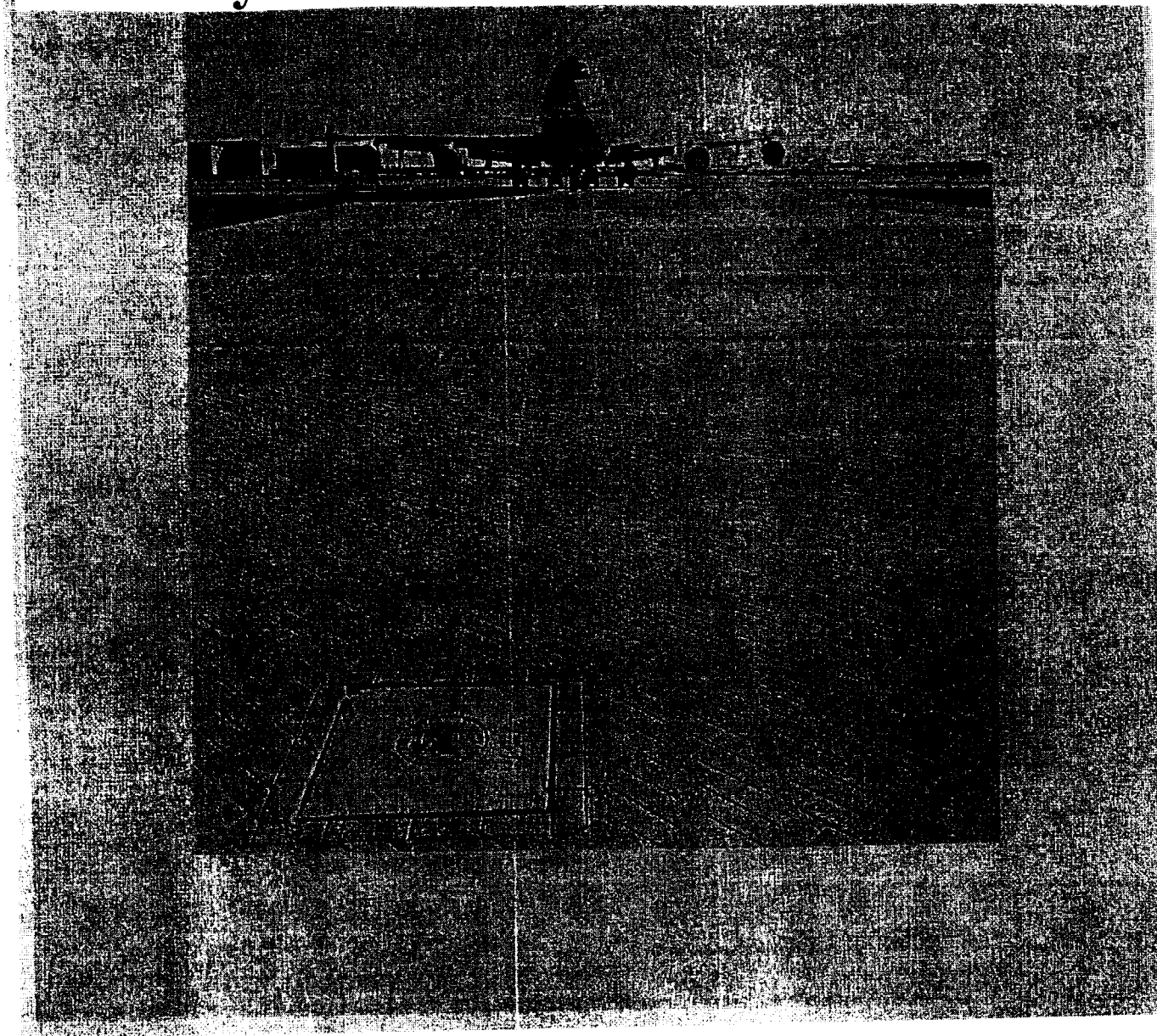


Figure 8

# Asphalt Runway Surface at Wallops

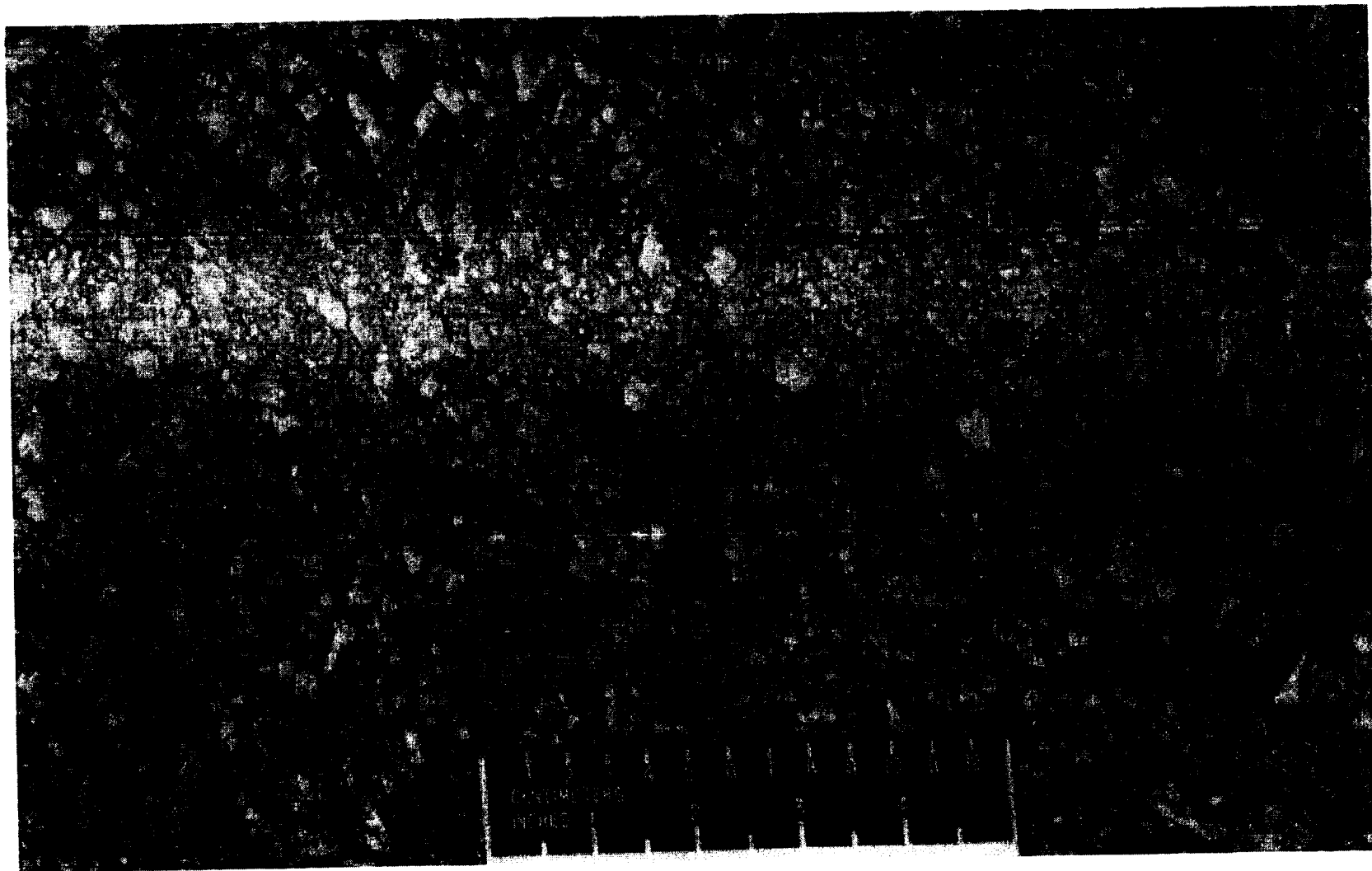


Figure 9



### Graded Asphalt Matrix Comparison

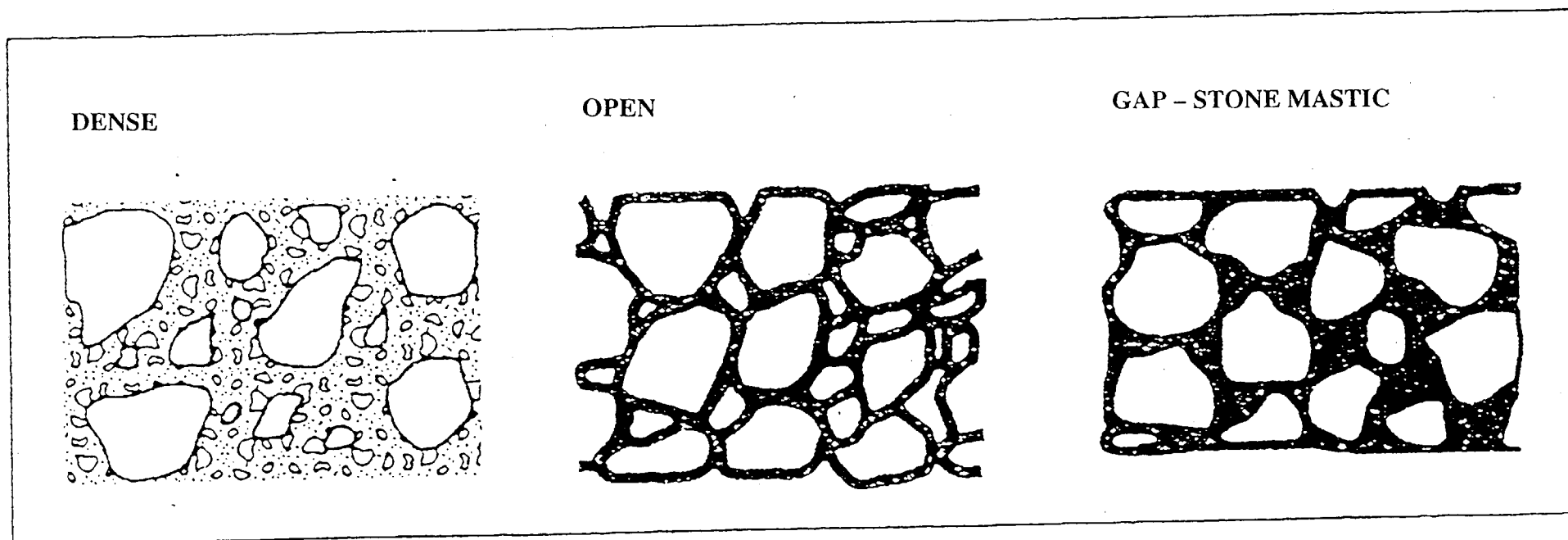


Figure 10

# Asphalt Overlay Surface at Wallops

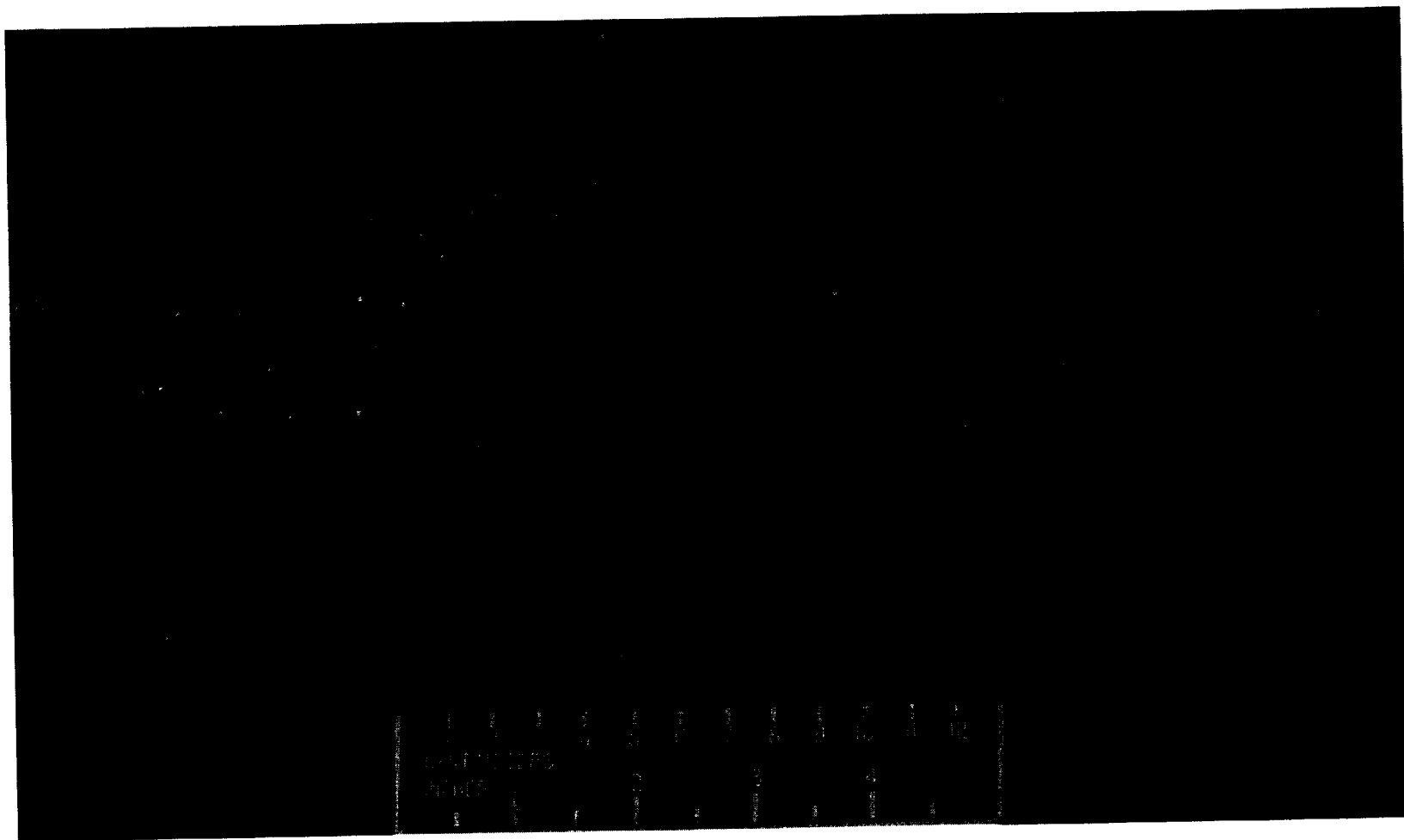


Figure 11

## Porous Friction Course Surface vs Asphalt



Figure 12

# CLASSIFICATION OF PAVEMENT SURFACES

CLASS	TYPE OF SURFACE	HYDROPLANING POTENTIAL	MACROTEXTURE DEPTH, MM (IN.)	
			GREASE SAMPLE METHOD	SAND PATCH METHOD
I	DEEP GROOVING OPEN TEXTURE POROUS FRICTION COURSE	LOW	>1 (0.04)	>1.8 (0.07)
II	SHALLOW GROOVING SCORING AND WIRE COMBING SOME LARGE AGGR. ASPHALT	POOR	1 (0.04) TO 0.5 (0.02)	1.8 (0.07) TO 0.9 (0.035)
III	HEAVILY TEXTURED CONCRETE SOME MIXED-GRADATION AGGREGATE ASPHALT	FAIR	0.5 (0.02) TO 0.3 (0.01)	0.9 (0.035) TO 0.6 (0.024)
IV	LIGHTLY TEXTURED CONCRETE SOME WORN AND TRAFFICKED MOST SMALL AGGR. ASPHALT	GOOD	0.3 (0.01) TO 0.1 (0.004)	0.6 (0.024) TO 0.25 (0.01)
V	VERY LITTLE TEXTURE PAINTED AND RUBBER COATED SOME HEAVILY TRAFFICKED	HIGH	<0.1 (0.004)	<0.25 (0.01)

Figure 13